Temperature Effects of an Artificial

HOTSPOT

Embedded in Stored Grain

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TEMPERATURE EFFECTS OF AN ARTIFICIAL HOTSPOT EMBEDDED IN STORED GRAIN

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SUMMARY

This publication reports observations on the heat-transfer patterns of a heat source buried in shelled corn. Localized heating in stored grain is commonly referred to as a "hotspot" by commercial elevator operators and warehousemen. Since this term has a definite and generally consistent meaning to the grain trade, the heat source used in these tests to simulate heating in stored grain is referred to by the same term.

Local heating in stored grain was simulated by artificial hotspots of two sizes embedded in 3,300-bushel circular steel bins, filled with shelled corn with moisture contents ranging from 12.5 to 13.5 percent. After the shelled corn was cooled by aeration, the electrically heated hotspot was energized and maintained at a surface temperature of about 105° F. The changes in corn temperatures were indicated by thermocouples placed in the grain. Moisture changes in corn above the hotspot were determined periodically by sampling, although this report is concerned primarily with temperature effects.

A 6-inch-diameter hotspot produced temperature increases in corn of 2° F. or more for a distance of about $1\frac{1}{2}$ feet laterally from the hotspot, and $3\frac{1}{2}$ feet above it. Temperature changes of 5° F. or more extended $2\frac{1}{2}$ feet laterally and 4 to 6 feet vertically from a larger 20-gallon oil-filled hotspot. The energy input to the smaller hotspot averaged only 5 watts, while the average input to the larger hotspot varied from 25 to 44 watts in three tests.

The top foot of grain above the larger hotspot increased 3 percent in moisture content during a 165-day test. Lesser increases were measured in shorter tests.

Convection played an important part in the pattern of heat transfer through the grain from the hotspot. The air movement carried heat up from the hotspot and resulted in grain temperature increases extending only half as far laterally from the hotspot as was predicted by calculations based on heat conduction only.

THE PROBLEM AND TEST PROCEDURES

The response of grain to heating from within its bulk, or from its surroundings, is rather complex. Grain has a low thermal conductivity, is granular with air spaces in the mass, and is hygroscopic. Therefore, heat transfer within the stored grain embraces more than one method of heat transmission: (1) Conduction from grain to grain; (2) convection by movement of air through the grain; and (3) transfer of moisture that evaporates from warmer parts of the grain mass and is absorbed or condensed in the cooler parts.

If all heat transfer were by conduction, temperature patterns within the grain mass could be predicted. Oxley 3/, 4/ published values for the conductivity of several grains, and suggested methods of predicting heat losses from stored grain. Oxley also discussed the possible importance of convection and accompanying moisture movement in large masses, but was unable to evaluate these factors in his laboratory tests.

The purpose of this study was to determine experimentally and to present graphically the heat-transfer pattern from a hotspot of fixed size and temperature embedded in a typical bin of shelled corn. There was no attempt at an exhaustive study of the thermophysical properties of the grain bulk; the limited analysis presented serves only to project the observed results to other sizes, types, and conditions of grain storage.

The sizes and temperature of the hotspots were selected to simulate localized heating from insect or mold activity. Four tests were completed with artificial hotspots operated at a temperature of 105° F. The first test used a 6-inch diameter air-filled copper sphere heated with a 25-watt thermostatically-controlled electric heater (fig. 1).

3/ See footnote 1, page 2.

4/ Oxley, T.A. The Properties of Grain in Bulk. III. The Thermal Conductivity of Wheat, Maize, and Oats. Soc. Chem. Indus. Jour. 63: 53-55. London. 1944.

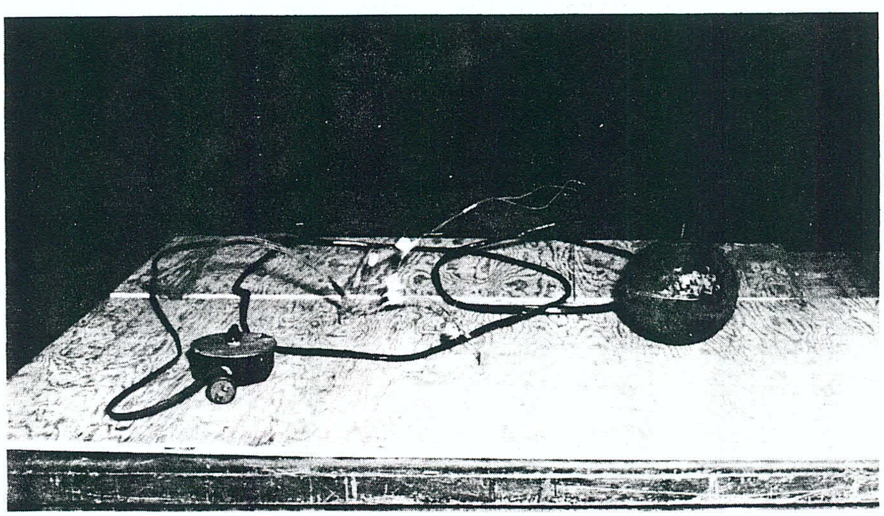

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Figure 1.--Six-inch artificial hotspot used in 1957 test.

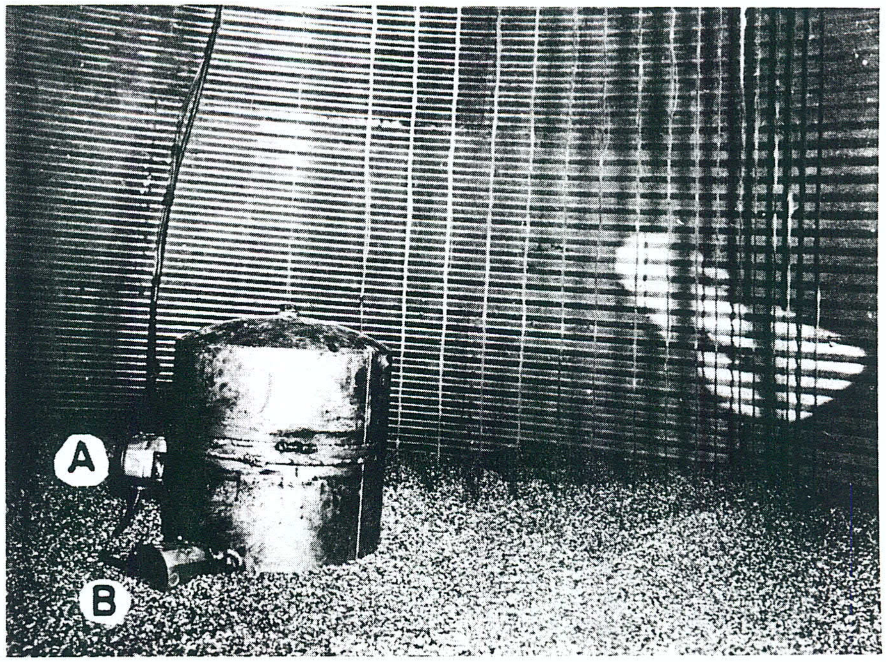

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Figure 2.--The hotspot positioned adjacent to the thermocouple cables in the half-filled bin; A - thermostat, B - heater.

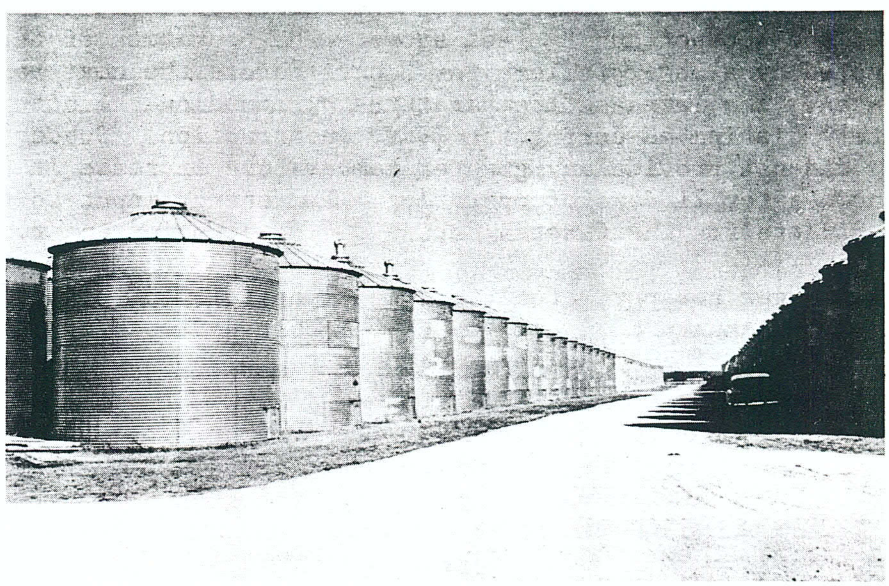

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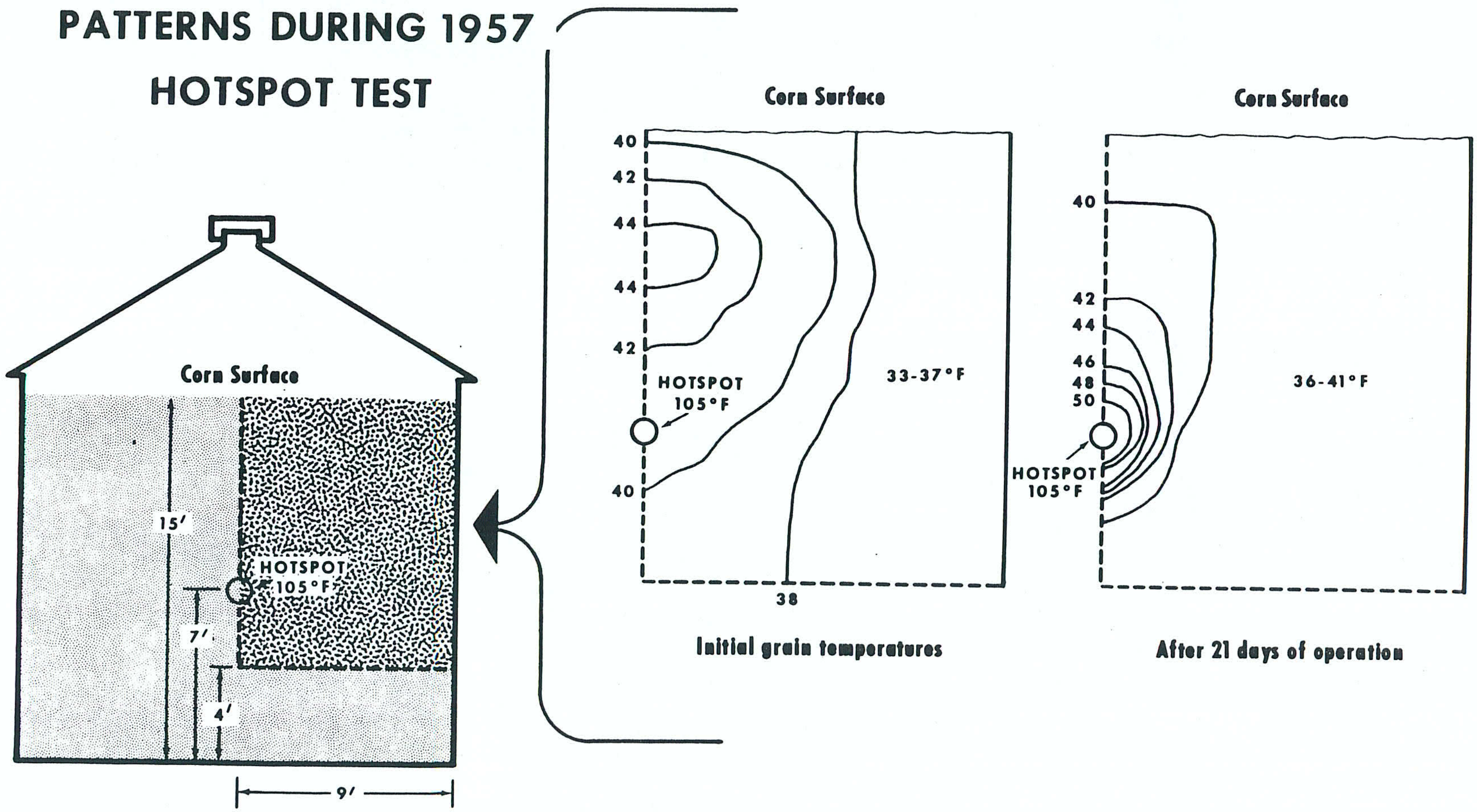
Figure 3.--The hotspot tests were conducted in these 3,300-bushel grain bins.

CORN TEMPERATURE PATTERNS DURING 1957 HOTSPOT TEST



The dark area in the filled bin indicates the location where the corn temperatures were taken.

Initial grain temperatures

After 21 days of operation

Twenty-one days after this test was started, operation was interrupted b a faulty electrical connection for a period of about 1 week. The repairs wer made on the afternoon of February 10, and the test was resumed. About 3 days of hotspot operation were required to regain the temperature pattern recorded 4 days before the interruption. The test was stopped on March 11, after 26 days more. At that time, the 40° F. corn temperature line was positioned about 2½ feet laterally from the side of the hotspot and 7 feet above it--almost to the corn surface. The energy input to the hotspot averaged 35 watt The energy consumption in kilowatt-hours during the test period is shown in figure 6.

The moisture content of the corn was measured at monthly intervals in th(1958 test. Samples were taken from each of the top 4 feet of corn at the bin center and halfway between the center and the wall. The moisture in the top foot of grain at the center and above the hotspot increased from 14.1 percent to 15.1 percent during the test. This compares with 0.2 percent increase in the top foot at the other sampling location. No measurable moisture changes occurred below the top foot.

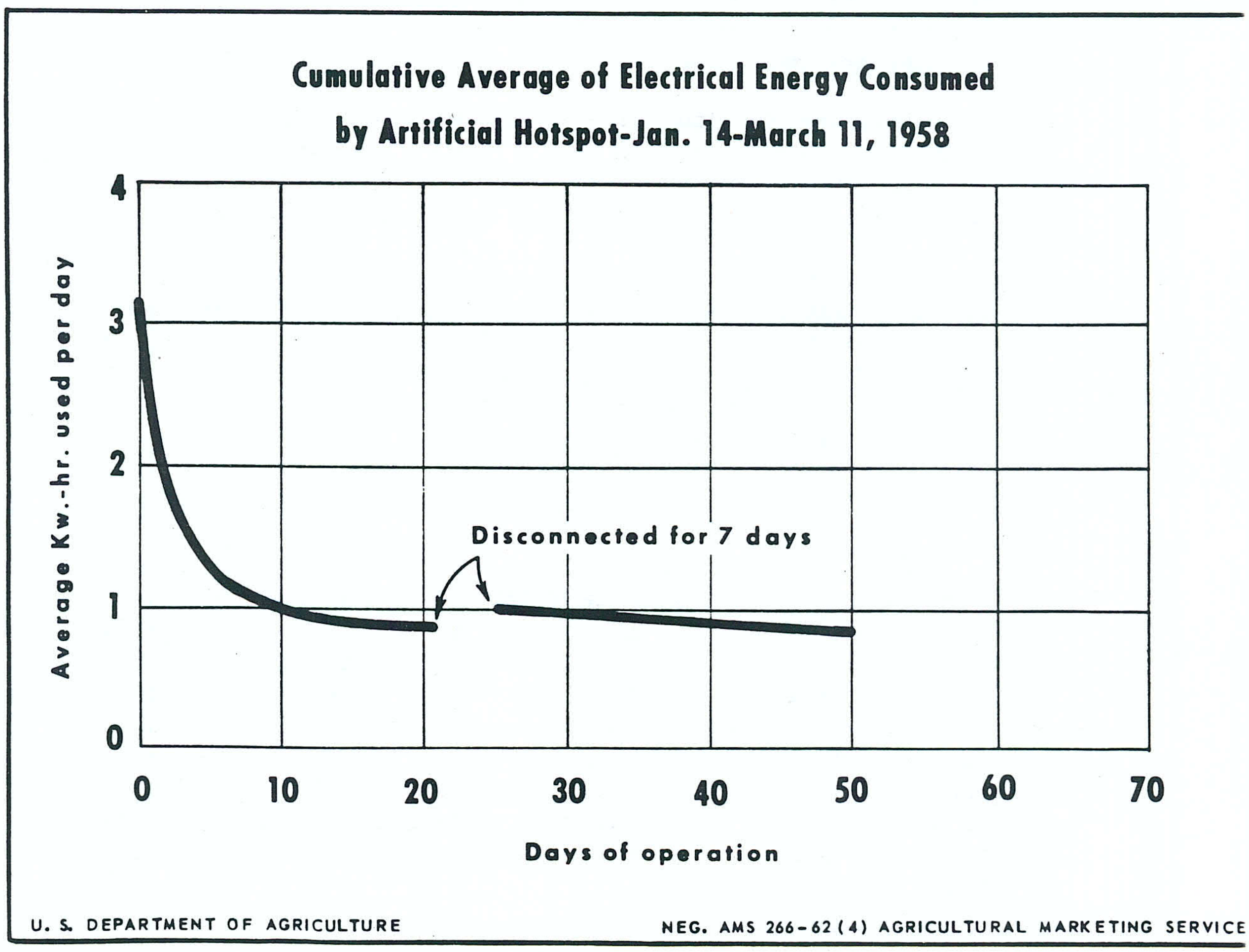
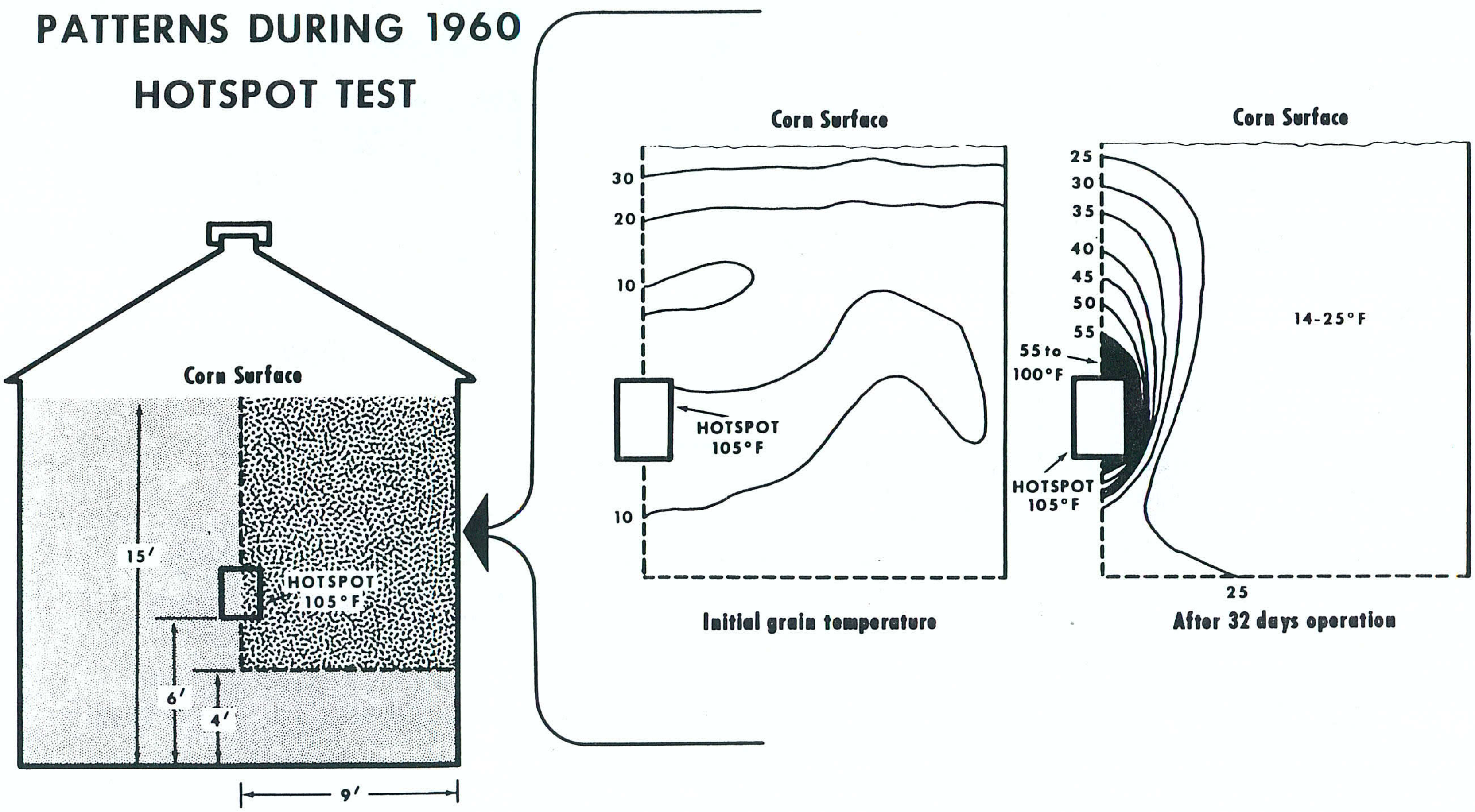


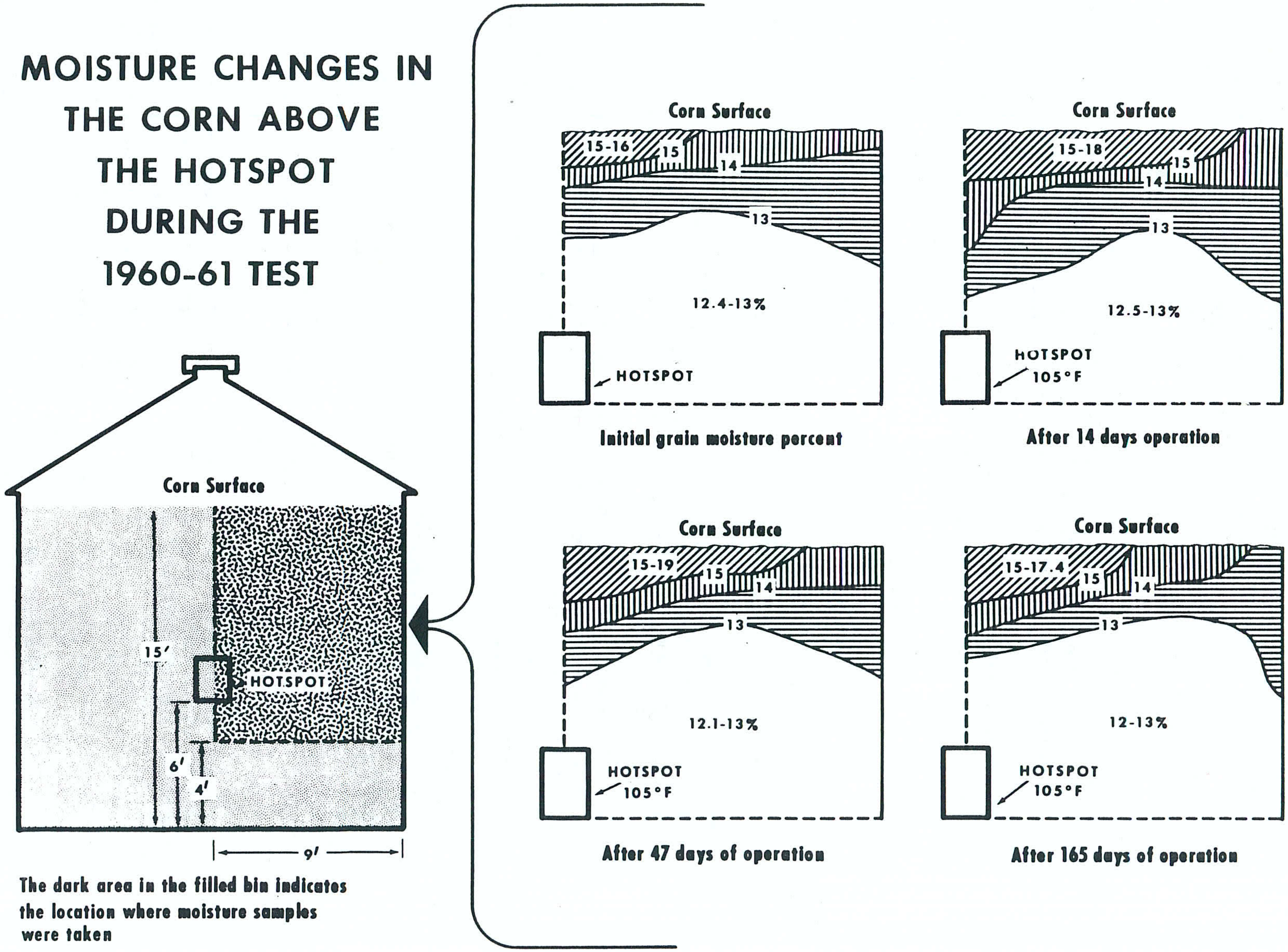
Figure 6

CORN TEMPERATURE PATTERNS DURING 1960 HOTSPOT TEST



The dark area in the filled bin indicates the locations where the corn temperatures were taken

MOISTURE CHANGES IN THE CORN ABOVE THE HOTSPOT DURING THE 1960-61 TEST



The dark area in the filled bin indicates the location where moisture samples were taken

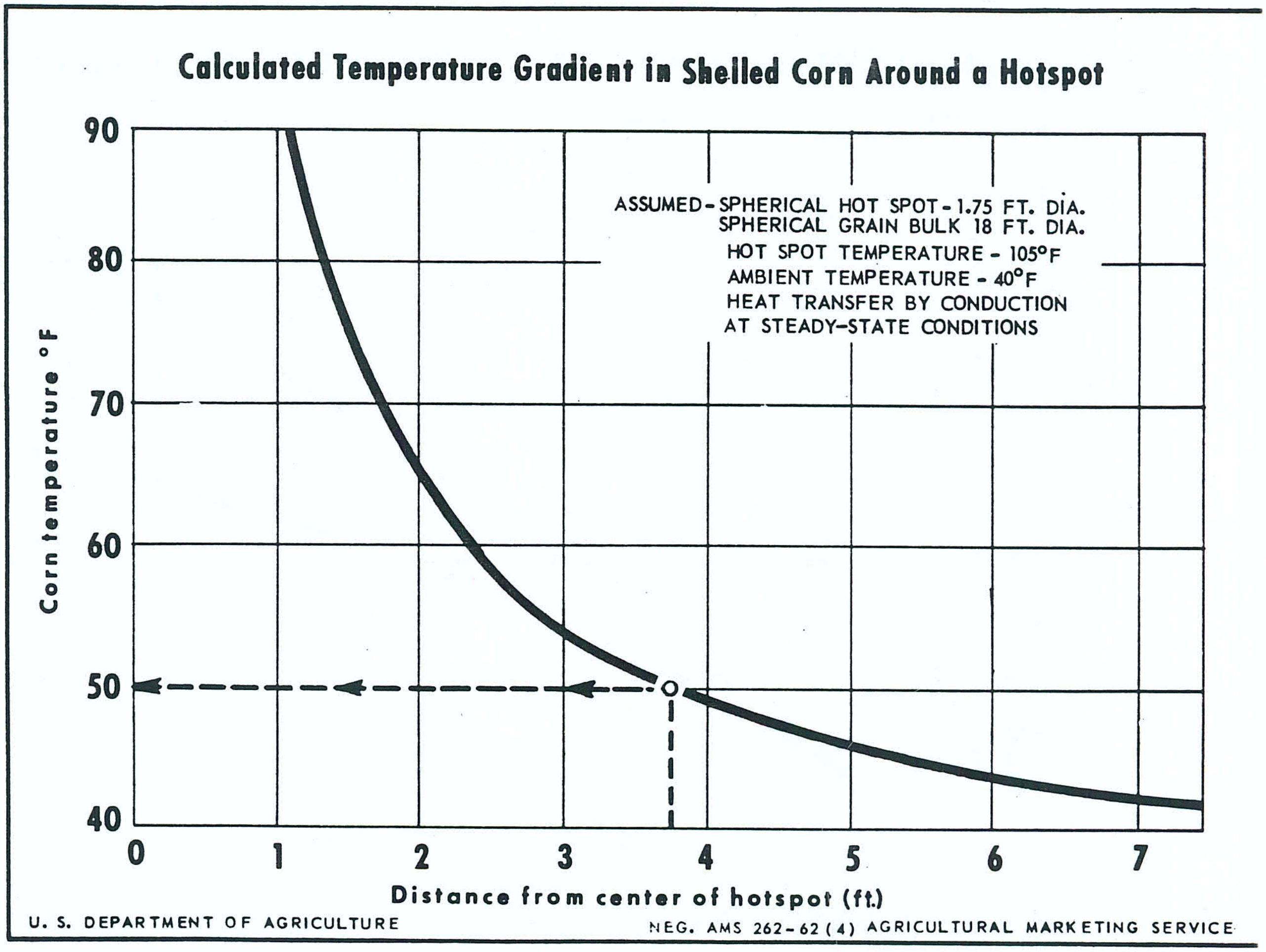


Figure 10

APPLICATION OF RESULTS

The temperature patterns observed in grain around a hotspot of fixed size, show that the lateral movement of heat from the hotspot is limited, and is less than half that predicted by heat-conduction equations. The upward movement of heat from the hotspot is aided by air movement within the grain mass, and tends to extend the heating area to the surface. The results of these tests confirm the usefulness of the practice of inspecting the grain surface for indications of heating.

The location of the hotspot within the grain bulk affects the temperature changes in the surrounding grain. Obviously, the heat from a hotspot near the grain surface will be more rapidly dissipated to the outside. On the other hand, if heating grain is buried deep within a large grain mass, most of the heat produced will be reflected in temperature changes in the surrounding grain.

It should be emphasized that grain temperature measurement systems are valuable in other ways than detecting small heating areas. They are used to determine the average grain temperature, which is important in the control of mold and insect growth; to determine variation in grain temperatures that leads to moisture migration and accumulation; 8/ and they are essential as an operating guide for aeration.

8/ See footnote 2, page 2.